RISK FACTORS FOR RUPTURE OF CHRONIC TYPE B DISSECTIONS

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Objective: **This study was an attempt to determine risk factors for rupture and to improve management of patients with type B aortic dissection who survive the acute phase without operation.** ***Methods:*** **We studied 50 patients by means of serial computer-generated 3-dimensional computed tomographic scans. All patients who did not undergo operative treatment before the completion of at least 2 computed tomographic scans a minimum of 3 months apart after an acute type B dissection were included in the study. The median duration of follow-up was 40 months (range 0.9-112 months). Only 1 patient died of causes unrelated to the aneurysm during follow-up. Nine patients had fatal rupture (18%); 10 patients underwent elective aneurysm resection because of rapid expansion or development of symptoms, and 31 patients remained alive without operation or rupture. Possible risk factors for rupture in patients in the rupture, operative, and event-free groups were compared, as were dimensional data from first follow-up and last computed tomographic scans.** ***Results:*** **Older age, chronic obstructive pulmonary disease, and elevated mean blood pressures were unequivocally associated with rupture (rupture versus event-free survival, $P < .05$), and pain was marginally significantly associated. Analysis of dimensional factors contributing to rupture was complicated by the fact that patients who underwent elective operation had significantly larger aneurysms and faster expansion rates than did either of the other groups, leaving comparisons of aneurysmal diameter between groups with and without rupture showing only marginal statistical significance. The last median descending aortic diameter before rupture in the rupture group was 5.4 cm (range 3.2-6.7 cm).** ***Conclusions:*** **In an environment in which patients with large and rapidly expanding aneurysms are usually referred for surgical treatment, older patients with chronic type B dissections, especially if they have uncontrolled hypertension and a history of chronic obstructive pulmonary disease, are significantly more likely to have rupture than are younger, normotensive patients without lung disease. Neither the presence of a persistently patent false lumen nor a large abdominal aortic diameter appears to increase the risk of rupture. Overall, our nondimensional data strikingly resemble the natural history of patients with nondissecting aneurysms, suggesting that calculations derived from data on chronic descending thoracic and thoracoabdominal aneurysms would provide an overly conservative individual estimate of rupture risk for patients with chronic type B dissection, who tend toward earlier rupture of smaller aneurysms. A more aggressive surgical approach toward treatment of patients with chronic type B dissection seems warranted. (J Thorac Cardiovasc Surg 1999;117:776-86)**

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The gradual improvement in recent years in results after surgery for acute dissections of the aorta has resulted in a consensus favoring operative intervention for almost all type A dissections and an increasing number of type B dissections. Although most surgeons now agree that immediate operation for an acute type B dissection is appropriate if there is intractable pain, uncontrollable hypertension, or serious organ malperfusion, the indications for surgery among those patients who survive the acute phase of a type B dissection without these complications are not as clear.[1] Thus the patient with a chronic type B dissection poses a dilemma similar to that of the patient with a nondissecting chronic descending thoracic or thoracoabdominal aneurysm. The risk of rupture, which is usually fatal, must be balanced against the not inconsiderable morbidity and mortality rates carried by elective surgery.[2]

As the result of a recent study of the natural history of chronic degenerative aneurysms in the descending and thoracoabdominal aorta, it is now possible to calculate a probability of rupture within a year for these aneurysms if one has knowledge of specific characteristics of the aneurysm and of the patient's general medical history.[2] Because it has long been suspected that chronic dissections may behave differently from other types of aortic aneurysms,[3] however, patients with chronic type B dissection were excluded from the earlier analysis of descending thoracic and thoracoabdominal aneurysms. In this study we therefore examined patients with chronic type B dissections separately to try to determine the specific risk factors that predispose toward the rupture of these aneurysms.

As in the previous study involving nondissecting aneurysms,[2] patients in this study were followed with serial 3-dimensional reconstructions of computed tomographic (CT) scans. Patients were included after a type B dissection if they were not operated on immediately and then underwent more than 1 scan beginning 3 months after the acute dissection. During the course of the study some patients underwent resection of their type B dissections because of rapid growth or development of symptoms, some other patients had rupture of their aneurysms, and most continued alive and well without rupture or operation. Although the numbers of patients with chronic B dissection were not large enough to permit the kind of analysis that would allow construction of an equation to predict probability of rupture, the data do permit comparisons of the 3 outcome groups with respect to factors suspected of predisposing toward rupture. These data should allow us to better discriminate those cases in which the risk of elective surgery for chronic type B dissection is warranted because rupture is imminent.

Material and methods

Patient selection. Between 1988 and 1997 a total of 120 patients with type B dissection were evaluated at Mount Sinai Medical Center. Twenty-seven patients were operated on immediately for acute type B dissection and 43 patients (most initially seen with an already chronic type B dissection) underwent an operation after only a single CT scan. The remaining 50 patients, those with type B dissection who underwent at least 2 CT scans a minimum of 3 months apart beginning at least 3 months after the acute onset of their disease, were the subjects of this study. These are all the patients who survived at least 6 months after initial nonoperative treatment of type B dissection and in whom the rate of growth of the aorta during the chronic phase of type B dissection therefore could be calculated. Patients with residual type B dissection after repair of type A dissection were not included, and it is possible that a few patients, despite a firm recommendation for one treatment or the other, elected to undergo neither surgery nor subsequent surveillance and were unavailable for follow-up after their initial consultation for chronic type B dissection. The group of patients studied here thus comprises slightly more than half of all patients with chronic type B dissection coming to Mount Sinai Medical Center and overlaps only tangentially with the larger cohort of patients with type B dissection reported on earlier.[4]

Indications for surgery during the acute phase of type B dissection included large aneurysm size, intractable pain, uncontrollable hypertension, and malperfusion. Once the patient had survived the acute episode of dissection without surgical intervention, operation after an initial consultation for a now chronic type B dissection was usually recommended if the aneurysm exceeded 5 cm in maximal diameter or appeared to be expanding rapidly, if the patient reported continuing pain, or both. Nearly half the patients with chronic type B dissection seen at Mount Sinai were referred for surgery after only a single CT scan more than 3 months after the acute dissection and were therefore not included in the study. Of the 50 remaining patients initially enlisted in nonoperative follow-up—at the time of their second CT scan more than 3 months after acute dissection—10 were subsequently referred for surgery, 7 because of rapid aneurysm growth (>1 cm/y), 1 because of pain, and 2 with both pain and evidence of rapid aneurysm expansion. These patients comprise the operative group considered here.

The remaining 40 patients continued to be followed nonoperatively. They were counseled to stop smoking, treated for hypertension, given β-adrenergic blocking agents whenever possible if not already being treated, and asked to obtain CT scans with contrast (or magnetic resonance images) periodically, usually every 6 months. Of these patients, 9 died of rupture during the interval of surveillance, as verified by autopsy or careful follow-up inquiry; the cause of death of the remaining patient could not be ascertained. Rupture had not been anticipated and operation had not been advised in most of these cases, but the rupture group also includes some patients who refused operation or had strong contraindications to operation.

Clinical data. Clinical data were obtained from records of

Table I. *Follow-up of 50 patients with chronic type B dissection*

	No rupture or operation (n = 31)		*Rupture (n = 9)*		*Operation (n = 10)*		*All patients (n = 50)*	
Time (mo)	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*
From acute dissection until first follow-up CT scan	8.3	2.1-90.6	8.6	4.9-74.2	5.9	2.8-13.1	8.2	2.1-90.6
From acute dissection until last CT scan*	45.1	3.7-117.1	37.4	4.9-87.3	13.9	2.8-88.9	37.4	2.8-117.1
From last CT scan until last follow-up†	12.5	2.9-74.3	7.0	2.0-14.8	2.3	0.4-23.6	10.2	0.4-74.3
From first follow-up CT scan until last follow-up	46.9	12.9-112.1	26.8	3.9-57.4	12.2	0.9-106.5	39.5	0.9-112.1

*Last CT scan refers to last CT scan in this study. It was the penultimate CT scan of event-free patients who had <6 months' follow-up after their actual last CT scan.
†Last follow-up is date of rupture, operation, or last date at which the patient was confirmed as alive without rupture or operation.

office visits, calls to patients or their relatives, and conversations or correspondence with referring physicians. Most patients had only a single visit for evaluation and then were followed by the referring physician; CT scans were obtained locally and sent to Mount Sinai for processing and interpretation.

Pain was considered to be present if the patient reported chest, back, neck, or abdominal pain at follow-up visits. Pain at the time of the acute dissection was not considered relevant. It is important to recognize that pain unequivocally related to the aneurysm was considered an indication for operation, so that the pain being reported by these patients at follow-up was generally sufficiently vague or mild to be deemed unrelated to the aneurysm by the examining surgeon at the time of the report.

Chronic obstructive pulmonary disease (COPD) was considered present if the patient reported shortness of breath on even mild exertion or had been reported to have significant lung disease on the basis of previous examinations of pulmonary function or other tests. Although forced expiratory volume in 1 second is currently measured as part of aneurysm follow-up, the values among the fraction of patients in whom this variable was measured were no more predictive of aneurysmal rupture than was a history of COPD in our previous study of degenerative thoracoabdominal aneurysms.

Although a detailed smoking history was elicited, no attempt was made to quantify smoking behavior because of the small numbers of patients in the study. A patient was considered a smoker if he or she had ever smoked, and we did not try to ascertain which patients were continuing to smoke despite having been advised to stop.

A history of hypertension was sought, but systolic and diastolic blood pressures were also measured or inquired about after the acute dissection, during follow-up. The treatment of hypertension was not standardized because many primary physicians were involved in regulating blood pressure, but all patients were advised to have their hypertension treated, to monitor it closely, and to use β-adrenergic blocking agents if possible. The mean pressure was calculated according to the following formula: [systolic pressure + 2(diastolic pressure)]/3. Values were obtained from either the sole office visit during which blood pressure was recorded or the most recent office visit during which blood pressure was recorded.

The determination of the time elapsed since acute dissection and the determination of whether the false lumen of the dissection was still patent was made by an experienced cardiothoracic surgeon on review of the patient's chart and the CT scans.

Aneurysm size and growth rate. Comparison of serial CT studies was carried out as previously described in detail.[2,5] In addition, a single trained and experienced technician unaware of the fates of individual patients redigitized the scans from almost all participants in the study to ensure accuracy and consistency of measurements because the presence of a false lumen may complicate assessment of the outline of the aneurysm in cases of dissection.

Comparisons were begun with the second scan after the acute dissection, a minimum of 3 months after the acute event. This is referred to as the first follow-up scan. In event-free patients, those without operation or rupture, the most recent scan was compared with the initial follow-up study if 6 months of uneventful follow-up could be documented. If the interval between the last scan and the latest follow-up ascertainment was less than 6 months, the penultimate scan was used to be sure of a 6-month interval of rupture-free survival in each instance. In patients who underwent operation or had rupture, the last scan before the event was the final study considered. Annual rates of change were calculated simply by dividing the changes in dimensions by the days elapsed between studies and then multiplying by 365.

In addition to the comparisons of patients without operation or rupture, patients who underwent operation, and patients who had rupture, a forward-looking piecewise exponential model was also used to evaluate risk factors for rupture, as has been described in detail previously.[2] For this analysis all the interim scans (between the first follow-up and last CT scan) were used, and patients who subsequently underwent operation were included as free of rupture until their penultimate scans because they could be documented to have been free of rupture for all earlier intervals.

As described previously in much greater detail, the diameter noted as the maximal diameter in the descending thoracic or in the abdominal aorta is actually the largest minimal diameter in the area of maximal dilatation of the aorta in each segment. This is an attempt to estimate the true diameter of the aorta in a plane perpendicular to the long axis of the aorta to emphasize the physiologically relevant dimensions of the aorta and to minimize errors resulting from oblique CT slices.[2, 5]

Follow-up intervals. Many patients underwent more than the 2 follow-up studies considered in the tables. The median number of studies for the entire study population was 4, with a range of 2 to 17. The median length of nonoperative follow-up was 40 months (range 0.9-112 months); the median interval between acute dissection and the first follow-up study was 8 months, and the median interval between the first scan and last follow-up was 37 months (range 2.8-117).

The median time between onset of nonoperative follow-up and rupture was 27 months and the median time between acute dissection and rupture was 51 months. Patients selected for operation had the shortest duration of follow-up, with a median of 12.2 months. Other comparisons of follow-up data in the various outcome groups are shown in Table I.

Statistical methods. Pairwise comparisons of the demographic and dimensional data between patients in the various outcome groups previously defined were undertaken with the χ^2 and Fisher exact or Wilcoxon tests of significance, as appropriate. The assumptions necessary for use of the piecewise exponential model previously described in detail[2] were once again found to be appropriate, and some analyses were also carried out with this model. Only univariate analyses were carried out because of the small numbers of patients with rupture of the dissecting aneurysm. All calculations were implemented with SAS programs (SAS Institute, Cary, NC) on a VAX computer.

Results

Demographic data. The demographic variables for the entire group of patients with chronic type B dissections (Table II) show many of the same characteristics seen in patients with nondissecting aneurysms that were treated nonoperatively. Most of the patients in both studies were male, but the patients with chronic dissection were on average 7 years younger than were patients with nondissecting aneurysms being followed up nonoperatively ($P < .003$). Most of the patients had a history of smoking, and almost three quarters had a history of hypertension. One third of the patients had ongoing complaints of chest or abdominal pain. A significant minority had a history of COPD, but very few had diabetes. In most cases the false lumen created by the aortic dissection continued to be patent.

In this study an attempt was also made to determine the actual blood pressures of the patients at some point during follow-up, because inadequate control of blood pressure is generally thought to predispose toward rupture. These figures, also shown in Table II, document that blood pressure, especially systolic blood pressure, was not adequately controlled in many patients despite the fact that three quarters were being treated with β-adrenergic blocking agents.

Table II. *Demographic and dimensional data in 50 patients with chronic type B dissection*

	%	*Median*	*Range*
Male gender	62		
Age at first follow-up CT scan (y)		63	43-84
Uncharacteristic pain	36		
COPD	20		
Smoking	58		
Hypertension history	74		
Systolic blood pressure (mm Hg)		140	100-230
Diastolic blood pressure (mm Hg)		80	60-120
Mean arterial pressure (mm Hg)		100	73-157
Diabetes	2		
False lumen open	72		
Descending diameter at first follow-up CT scan (cm)		4.7	3.1-6.7
Descending diameter at last CT scan (cm)		5.0	3.2-7.1
Abdominal diameter at first follow-up CT scan (cm)		3.7	2.3-5.8
Abdominal diameter at last CT scan (cm)		3.9	2.0-7.0

If the variables in Table II are compared for the 3 outcome groups (Table III) several interesting differences emerge between the group of patients who had rupture and both groups without rupture. Patients whose aneurysms subsequently ruptured had a significantly higher incidence of COPD and significantly higher diastolic and mean blood pressures than did those who were not operated on and did not have rupture. They also tended to be older, tended to have higher systolic blood pressures, and were more likely to have reported pain during follow-up, although none of these observations was statistically significant, possibly because of the small numbers of patients involved.

When the 10 patients who were selected for operation are compared with the other groups, another set of interesting observations emerges. In contrast to the patients with rupture, none of the patients operated on had COPD, and they were also significantly younger. Patients operated on were also more frequently normotensive, with significantly lower systolic, diastolic, and mean blood pressures than those who had rupture, even though all patients operated on had a history of hypertension. All patients operated on were also being

Table IIIA. *Categoric demographic variables in patients with chronic type B dissection in three outcome groups: Patients without rupture or operation, patients who died of aortic rupture, and patients who underwent elective operation*

				P		
Characteristic	*No rupture or operation (%, n = 31)*	*Rupture (%, n = 9)*	*Operation (%, n = 10)*	*None versus rupture*	*None versus operation*	*Rupture versus operation*
Male	61.3	44.4	80.0	.46	.45	.17
Pain during follow-up	25.8	55.6	50.0	.12	.24	1.0
Diabetes	3.2	0	0	1.0	1.0	—
COPD	16.1	55.6	0	.03	.31	.01
Ever smoked	51.6	66.7	70.0	.48	.47	1.0
Hypertension history	64.5	77.8	100.0	.69	.04	.21
False lumen open	65.5	66.7	100.0	1.0	.08	.17
β-Blocker therapy	71.0	66.7	100.0	1.0	.08	.09

Table IIIB. *Continuous demographic variables in patients with chronic type B dissection in three outcome groups: Patients without rupture or operation, patients who died of aortic rupture, and patients who underwent elective operation*

	No rupture or operation (%, n = 31)		*Rupture (%, n = 9)*		*Operation (%, n = 10)*		P		
Characteristic	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*None versus rupture*	*None versus operation*	*Rupture versus operation*
Age at first follow-up CT scan (y)	62	43-84	70	59-79	62	49-80	.06	.46	.03
Age at last follow-up CT scan (y)	66	47-85	73	59-80	63	50-80	.11	.39	.03
Systolic blood pressure (mm Hg)	140	100-230	170	130-200	120	110-160	.09	.31	.02
Diastolic blood pressure (mm Hg)	80	60-120	95	70-120	80	60-100	.03	.40	.02
Mean arterial pressure (mm Hg)	100	73-157	117	93-147	93	80-113	.03	.38	.01

*Annualized change from first follow-up CT scan to last CT scan.

treated with β-adrenergic blocking agents. Although preoperative notes in the cases of patients operated on all cite recent enlargement or pain as the indications for surgery, it is difficult to rule out an unconscious bias toward operating on younger patients who were probably considered to be better surgical candidates. In fact, all patients operated on survived the operation, despite the necessity for cardiopulmonary bypass and hypothermic circulatory arrest to allow resection of the distal arch as well as the descending aorta in 6 cases and coronary artery bypass grafting in 2 cases.

Aneurysm size and growth rate. The data concerning the aneurysm itself (Table IV) confirm that selection of patients for operation reflected a desire to avoid impending rupture. The maximal descending thoracic diameters of aneurysms in patients operated on were significantly larger than those in patients not selected for operation, with higher median values even than those in patients who subsequently had rupture. Both these differences were marginally statistically significant. An even more striking pattern is seen in the rate of change, with significantly more rapid rates of expansion in the patients operated on than in the event-free patients and even somewhat more rapid rates in patients operated on than in patients who had rupture.

Perhaps because of the selection of patients with large and especially with rapidly expanding aneurysms for surgery, dimensional data did not reveal as many significant differences as might have been expected between the characteristics of dissecting aneurysms that eventually ruptured and those that did not (Table IV). The median maximal diameter in the descending

Table IV. *Dimensions of the aorta in 50 patients with chronic type B dissection*

	No rupture or operation (%, n = 31)		*Rupture (%, n = 9)*		*Operation (%, n = 10)*		P		
Maximal diameter (cm)	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*None versus rupture*	*None versus operation*	*Rupture versus operation*
Descending aorta at first follow-up CT scan (cm)	4.4	3.4-5.9	5.0	3.1-6.7	5.1	3.9-6.7	.17	.08	.65
Descending aorta at last follow-up CT scan (cm)	4.7	3.4-6.5	5.4	3.2-6.7	5.8	3.9-7.1	.22	.01	.29
Abdominal aorta at first follow-up CT scan (cm)	3.7	2.8-5.1	3.8	2.3-5.8	3.5	2.6-4.5	.57	.44	.31
Abdominal aorta at last follow-up CT scan (cm)	3.9	2.7-5.1	3.8	2.0-7.0	3.6	2.8-4.7	.52	.69	.31
Change* in descending aorta (cm/y)	0.09	–0.20-1.1	0.16	–0.16-1.4	0.42	0-4.8	.18	.001	.15
Change* in abdominal aorta (cm/y)	0.10	–0.09-1.7	0.22	–0.2-0.5	0.17	–2.0-3.5	.82	.73	.97

*Annualized change from first follow-up CT scan to last CT scan.

aorta in the group of patients with eventual rupture was marginally higher at the time of entry into the study (5.0 versus 4.4 cm), but at the time of the last scan before rupture this median (5.4 cm) was not significantly higher than that in those patients who survived without rupture (4.7 cm). The median of the descending aortic diameter in the last scan of the group without rupture, however, was significantly smaller than the median in the group selected for surgery (5.8 cm); the withdrawal of patients for operation thus removed a number of patients with large aneurysms from the group at risk for rupture.

The median rate of expansion in the group with rupture was marginally significantly higher than in control patients without rupture, despite the removal of the very rapidly expanding aneurysms of the operative group from the pool at risk. As previously noted, the operative group had much higher rates of expansion than did either of the other groups. Taken together, these data suggest that rapid expansion may herald rupture in chronic type B dissection.

All patients selected for operation had a patent false lumen: this most likely reflects a prevalence of patency of the false lumen in larger aneurysms. Again, however, an unconscious bias on the part of surgeons that a patent false lumen is dangerous may also have been present. No difference was seen between the rupture and the event-free groups in the incidence of a patent false lumen.

The small numbers of patients in this study and the withdrawal of patients with large and rapidly expanding aneurysms from the pool at risk make it difficult to demonstrate unequivocally that large aneurysmal size and rapid expansion rate are risk factors for rupture in type B dissection, although we continue to believe strongly that they are. In contrast there is no evidence to suggest that the absolute value of the abdominal aortic diameter or its rate of change is important in determining risk of rupture in type B dissecting aneurysms, in contrast with the evidence for degenerative aneurysms.

It is also of note that the median maximal diameter in the descending aorta in patients with rupture of type B dissections was significantly smaller than was the median maximal descending aortic diameter in patients who had rupture of nondissecting aneurysms in a previous study (5.4 versus 5.8 cm, $P = .05$). The relatively small median diameter of the dissections that ruptured during this study underscores the vulnerability of even a modestly enlarged but dissected aorta.

Summary of risk factors. The analysis of rupture risk was also carried out with the piecewise exponential model developed to study the natural history of nondissecting aneurysms.[2] Looking at the patients with chronic type B dissection in this somewhat different way, which allows incorporation of information from interim scans, the same risk factors for rupture previously determined were found by univariate analysis: age ($P = .05$), COPD ($P = .01$), mean arterial pressure ($P = .004$), and maximal diameter in the descending aorta ($P = .14$).

Survival. During the course of the study, 9 of the 10 patients who died succumbed to rupture, which was uniformly fatal. The overall rupture rate was 18%.

Fig 1 shows Kaplan-Meier estimates of the probability of freedom from rupture and of freedom from both rupture and operation for the patients in the study, beginning from the time of their entry into the study,

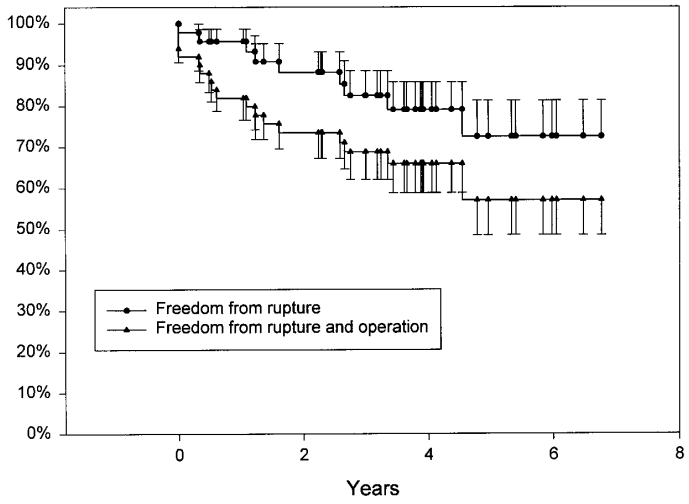

Fig 1. Kaplan-Meier estimates of freedom from rupture and freedom from both rupture and operation for 50 patients with chronic type B dissections, beginning from the time of entry into the study, after they had survived acute type B dissection without operative intervention, and after they had undergone 2 CT scans at least 3 months apart.

after they had survived acute type B dissection without operative intervention and had undergone 2 CT scans at least 3 months apart. In the freedom from rupture curve, patients subsequently selected for surgery were removed at the time of the operation. For this group of patients with chronic type B dissection under intensive surveillance, which allows periodic reevaluation of the need for surgery, one can predict that 90% will be free of rupture at 1 year from their first follow-up studies and 75% will be free of rupture at 5 years.

The second line in Fig 1 is an estimate of freedom from both rupture and operation for the same group of patients, beginning 3 months or more after acute dissection. The chances of survival of chronic type B dissection without operation or rupture were 80% at 1 year and 60% at 5 years, reflecting a significant possibility that operation will be recommended, especially within the first 2 years after acute type B dissection.

Discussion

The management of patients with moderately large chronic descending thoracic and thoracoabdominal aneurysms often involves difficult choices, and the management of the subset of these patients with chronic type B dissection continues to be among its most frustrating aspects. Because serious early complications of type B dissection are not uncommon and unexpected late rupture cannot reliably be predicted and is almost invariably fatal,[3, 6] there has been an increasing tendency to operate on acute and subacute type B dissections.[1, 7] Higher rates of surgical intervention have gradually removed increasing numbers of patients with type B dissections from further follow-up and will probably continue to compromise attempts to understand the factors that predispose toward rupture in this relatively rare condition.

Although we were aware of the inherent difficulties of a natural history study under these circumstances, we nevertheless undertook an examination of 50 patients with chronic type B dissection initially assigned to nonoperative follow-up. These patients comprise only slightly more than half of all patients with chronic type B dissection referred to Mount Sinai. Our aim was to try to determine the factors associated with enhanced risk of rupture of chronic type B dissections and whether they differ significantly from the risk factors for rupture of other chronic aneurysms in the descending thoracic and thoracoabdominal aorta, to further refine our indications for elective operative intervention in this disease.

A history of COPD was a powerful predictor of rupture of chronic type B dissection in this study, as was previously shown to be the case for nondissecting thoracic and thoracoabdominal aneurysms.[2, 8] COPD was first recognized as being associated with a high risk of rupture of aneurysms in the abdominal aorta by Cronenwett and associates,[9] and it has been speculated that there must be a common, possibly smoking-related defect in connective tissue metabolism that predisposes toward both lung and aortic pathology in susceptible persons.[10] What is striking in this study is the absence of any patients with COPD among the group recommended for operation. This was the case even though we have been aware of the association of COPD

with aneurysm rupture. The failure to include any patients with COPD in the operative group in this study underscores most surgeons' reluctance to undertake extensive aortic surgery in patients with pulmonary compromise, even though results in patients with moderate degrees of pulmonary dysfunction do not justify a refusal to operate under these circumstances.[11]

Another common factor predisposing toward rupture in this study was patient age. As with nondissecting aneurysms, older patients were more likely to have rupture than were younger patients. The fact that most patients operated on—and presumably therefore thought to be at higher risk for rupture—were younger than the mean of the group as a whole may have enhanced the apparent importance of older age as a risk factor for rupture in this study, but age has been found to be a risk factor for rupture in other aneurysm studies and the influence of age is therefore likely to be a real phenomenon.[2, 6, 12]

We were somewhat surprised to find that aneurysm size, as defined by maximal diameter in the descending thoracic aorta and various other dimensional variables, was, on careful review of serial studies and elimination of some improperly classified patients, apparently not a significant factor predisposing toward rupture. To interpret this finding appropriately it is important to keep in mind that many patients with acute type B dissections and nearly half those with chronic type B dissections were never entered into the study or were removed early in the course of follow-up for operative intervention, often because of large aneurysm size. In fact, even the subset of surgical patients who were selected for operation after having been entered into the study had significantly larger aneurysm diameters and higher rates of expansion than did those who subsequently had rupture. By using aneurysm diameters and rates of expansion as indications for operative intervention, we almost certainly removed so many patients with large aneurysms from the pool of patients at risk for rupture that we seriously impaired our ability to demonstrate the contribution of size and rapid expansion to rupture.

It should be noted that the average maximal diameters of the chronic type B dissections that ruptured in this study were significantly smaller than the comparable dimensions of nondissecting thoracic aneurysms that ruptured in our previous study.[2] The relatively small median size of the dissections that ruptured in this study in our minds justifies a continued policy of elective operation for large type B dissections on the basis of their size, despite our failure to demonstrate in this study that large size is a risk factor for rupture.

This study also suggests that the continued patency of the false lumen is not an important predictor of rupture. Patency of the false lumen is thought by some authors to contribute to risk of rupture.[13] A straightforward comparison of the percentage of patients with patent false lumen shows no difference at all between the groups with and without rupture. It is true that all patients operated on had a patent false lumen, and so a disproportionately high number of patients with a patent false lumen were eliminated from the group at risk. However, the absence of even a trend toward a lower patency rate in the event-free group makes us think that it is unlikely that patency of the false lumen would have emerged as a risk factor for rupture even if the patients operated on had all eventually had rupture.

In this study, in contrast to the previous study of nondissecting aneurysms, we had blood pressure measurements during follow-up in addition to a history of hypertension.[2] Despite the acknowledged importance of treating hypertension to prevent rupture, the blood pressures obtained during follow-up still showed a high prevalence of hypertension in the group as a whole. Furthermore, both diastolic and mean blood pressures were significantly higher in the patients who subsequently had rupture than in those without rupture. Paradoxically, the patients operated on were the only group with normal blood pressures, differing significantly in this respect from the group with rupture. These observations reinforce the need for better control of blood pressure in patients with chronic dissections, despite widespread use of β-adrenergic blockade, and for recognition of the importance of uncontrolled hypertension as a factor predisposing toward rupture.[14, 15]

This admittedly imperfect study suggests that older age, hypertension, and COPD are significant factors predisposing toward late, unexpected fatal rupture of chronic type B dissecting aneurysms. It documents that a significant number of patients with even relatively small chronic dissections have rupture when other risk factors—which perhaps should also include uncharacteristic pain, smoking, and renal failure—are present.[2, 6, 10, 14-16] In a climate in which patients with large or rapidly expanding chronic dissections are usually advised to undergo elective operation, further lowering the rupture rate requires acknowledging the importance of other risk factors and offering the option of operation to some patients with smaller dissections in whom these other factors suggest that rupture may be imminent, even though they may not be ideal surgical candidates. It should be noted in this context that only 1 patient in the entire follow-up group died of a cause other than rupture, so surgery is likely to be lifesaving in this relatively young cohort of patients with aneurysms.

Our surgical results after operation for acute type B dissection during the interval of this study show no

deaths and a single instance of paraplegia among 27 patients. Among 55 patients operated on for chronic type B dissection, there was an 11% mortality rate and a 7% incidence of paraplegia. Thus the overall surgical mortality rate for type B dissection rate was 7%, with a 6% incidence of paraplegia, with most of the mortality and morbidity occurring early in the experience. As previously noted, all the surgical patients in the study population survived late elective operation. It should be borne in mind that many of the patients with chronic type B dissection had large aneurysms requiring extensive operations, and often additional cardiac procedures such as coronary artery bypass grafting were also necessary. In view of these surgical results, and especially in light of recent changes in surgical techniques that have substantially reduced the incidence of paraplegia, a rupture rate of 18% among patients initially followed nonoperatively seems to justify a more aggressive surgical approach toward patients with type B dissection.[11]

A comparison of the results of this natural history study with our previous more extensive analysis of patients with nondissecting thoracic and thoracoabdominal aneurysms suggests that the same demographic factors play a role in enhancing rupture risk in both situations but that dissections seem more prone toward rupture at smaller sizes.[2] Calculation of rupture risk for a patient with a chronic type B dissection according to the formula developed for patients with nondissecting aneurysms would be likely to somewhat underestimate the risk of rupture, but it might nevertheless be helpful in trying to determine which individual patients with chronic type B dissections are most vulnerable.[2] This conservative but individualized estimate of rupture risk could then be weighed against the projected outcome of surgery for each patient, and additional patients likely to benefit from elective operation for chronic type B dissection could then be selected.

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Discussion

Dr D. Craig Miller *(Stanford, Calif).* I agree completely with some of your key clinical take-home messages, but I would like to reiterate some of them to make sure that my interpretation is correct.

First, the prognosis for patients with chronic type B aortic dissections that are not operated on is not as benign as many of us have been led to believe and, perhaps most importantly, these patients do not necessarily die of their other medical problems, as I think most of us would have predicted. I am sure that it was sobering for the surgeons at Mount Sinai to discover that 18% of these patients, although closely followed within their orbit, still died of aortic rupture within a relatively short period, 2 to 3 years.

Second, patients with chronic type B aortic dissections do have them rupture at a smaller size than would have been estimated previously.

Third, despite your best attempts to educate the cardiologists and internists, these patients in general are still not treated adequately in terms of antihypertensive and negative inotropic therapy.

From the Stanford perspective, I agree wholeheartedly that we have to be more aggressive surgically. And here I would urge that we throw out our traditional operative size thresholds. I would also like to reemphasize Dr Stanley Crawford's advice from more than 10 years ago that we should look at the maximal diameter of these chronic dissections and then try to identify a segment of relatively "normal" aorta somewhere, usually the transverse arch (although many of these patients with severe hypertension do not have a segment of normal aorta anywhere in their entire bodies: using this, we should consider operation at an earlier stage, when the maximal diameter of the dissected aorta approaches or exceeds twice the caliber of the undissected thoracic aorta.

I do have a criticism. Even though the article states that "it is difficult to rule out an unconscious bias" in terms of operating on younger patients without COPD and other risk factors, I think that it is in fact clear that the surgeons did do something equivalent to "picking some low-hanging fruit." The surgical results are outstanding, with no deaths in this subset and only a single case of paraplegia. However, this factor does weaken your natural history study because the numbers of patients are smaller and you were not able to prove conclusively that larger size, faster growth rate, or persistent patency of the false lumen predicted a greater likelihood of rupture.

So it boils down to a "good news, bad news" situation. The surgeons were trying to do what they thought best for each individual patient. However, we are now left with the same quandary as after the seminal thoracic aneurysm natural history paper from Mount Sinai. You found risk factors portending rupture, but unfortunately they are generally the same variables that place the patient at higher operative risk. Therefore, how does this knowledge really help us clinically in our decision making?

Second, did you glean any new knowledge from this study comparing the growth rate of chronic dissections versus aneurysms? You will recall that this was debated at the Mount Sinai Thoracic Aortic Symposium last Friday in New York.

Third, how often do you recommend that serial CT scans be done in these chronic type B dissections? I think one thing I have learned from your analysis is that CT or magnetic resonance imaging scans should be performed more frequently than we have been doing them in the past. Convincing health maintenance organizations and managed care medical directors to approve this, however, is another challenging issue.

Finally, I see an increasing trend toward operating on more patients with acute type B dissections at Mount Sinai and also at Yale, albeit on the basis of the same classic surgical indications employed in the past. Are you indeed operating more frequently in the acute phase of type B dissection, so as perhaps to minimize the long-term problem that you discuss here?

Dr Juvonen. In response to your first question, it must be admitted that even after this study the decision as to whether to operate on patients with chronic type B dissections remains a rather crude balancing act. How do our findings really help us clinically in decision making? The purpose of this study was to refine our understanding of factors that are related to rupture of chronic dissecting aneurysms. One striking finding, even after acknowledging that we "picked low-hanging fruit" by taking some patients with large aneurysms who were good operative candidates out of the pool at risk, was that patients in whom rupture occurred had a dissecting aneurysm of only moderate size, with a median maximal diameter of 5.4 cm. In addition, clinical parameters such as COPD, elevated blood pressure levels, and age were more predictive of rupture of chronic type B dissection than was aneurysm size. As you already emphasized, we must therefore pay more attention to meticulous control of blood pressure with adequate antihypertensive regimens. Perhaps the major message of this article, however, is that having determined which patients are at highest risk for rupture we should operate on them, even though these older patients, often with chronic lung disease, are those with the highest operative risk.

Your second question concerns the growth rates of degenerative aneurysms and dissecting aneurysms. The overall annualized growth rates of the maximal diameter in the descending aorta were pretty close to the same in the 2 groups of patients, approximately 0.2 cm/y. In comparing the patients in whom unexpected rupture occurred, however, the growth rate was 0.4 cm/y in patients with degenerative aneurysms[2] and 0.16 cm/y in this study of dissecting aneurysms. Once again, however, it must be emphasized that there was a bias in favor of selecting patients with faster-growing chronic dissections for operation. The annualized growth rate of the maximal diameter of descending aorta in those 10 patients was 0.4 cm/y.

In response to your third question regarding appropriate follow-up interval, I agree completely that serial CT scans should be performed on these patients with chronic type B dissection much more frequently. A CT scan should be done shortly after the acute phase and then probably every 3 months at least for the first year, rather than every 6 months. In this series we tried to follow these patients at 6-month intervals, but total follow-up time was 37 months and the median number of CT scans was 4, so we failed a little bit in our mission. These patients should be monitored more frequently, which would permit us at the same time to be sure that they are treated adequately in terms of hypertension control.

In response to your final question concerning whether patients with acute type B dissection should be operated on more frequently, I would like to refer briefly to the Mount Sinai experience. Looking at the operative risk of more than 50 patients who underwent surgery for chronic type B dissection at the time of this study, the mortality rate was 11% and the rate of paraplegia was 7%. In 27 patients who underwent surgery for treatment of acute type B dissection in a recent study by Schor and associates,[4] there were no deaths and again a 7% incidence of paraplegia. If we compare these surgical mortality rates with an 18% risk for spontaneous rupture, the comparison clearly supports operating on more

patients during the acute phase of the disease. Taking into account that the understanding of spinal cord protection has increased a lot during the past decade and that many seminal contributions in this field have demonstrated that dissection per se is not an independent risk factor for paraplegia, our conclusion is that a more aggressive approach to the treatment of patients with type B dissection is justified.

Dr Michael A. Coady *(New Haven, Conn).* We have followed the work of Dr Griepp with great interest for many years now on the natural history of thoracic aortic dissections and aneurysms. You have shown that the natural histories of aortic dissections and aneurysms are strikingly similar in terms of risk factors for rupture. How highly correlated are the risk factors that you have identified for rupture *with one another?* Do you speculate that your univariate, nonparametric results would hold up in a multivariate model with a larger sample size?

In 1997 our group found chronic dissection to be a risk factor for more rapid aneurysm growth. Do you have any evidence on the relationship between chronic dissection and aortic growth? Specifically, are the growth rates similar between thoracic aneurysms and dissections?

Dr Juvonen. Perhaps because patients with large and especially with rapidly expanding aneurysms were usually referred for operation, and also possibly because of the small numbers of patients with rupture of the aneurysm, growth rate was not found to be a significant risk factor for rupture of chronic type B dissections in our study. We therefore did not look at growth rate with other factors in a regression model.